

**MAGMATIC TEMPERATURES AND COMPOSITIONS ON EARLY MARS AS INFERRED FROM THE ORTHOPYROXENE-SILICA ASSEMBLAGE IN ALH84001.** D. A. Kring and J. D. Gleason, Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721 USA.

The cumulate orthopyroxenite ALH84001 represents the oldest igneous rock from Mars and the earliest available sample of primitive crustal material from a large terrestrial planet. It can thus provide us with a glimpse of the earliest conditions on Mars and, because similar material was destroyed on Earth, a hint of the conditions in the nascent stages of our own planet's evolution.

**Orthopyroxene-silica assemblage.** The principal magmatic constituent of ALH84001 is orthopyroxene, which comprises >90% of the rock. Within these cumulus crystals we found ~5 to 50  $\mu\text{m}$  long euhedral silica grains. Most of the silica grains have singly- to doubly-terminated forms, sometimes twinned, which are typical of high-quartz. A euhedral lath or needle-shaped polymorph, typical of tridymite, was also found. These silica morphologies indicate the grains crystallized at high temperatures and that the silica grew freely in a melt before being incorporated into cumulus orthopyroxene.

**Magmatic temperature.** An orthopyroxene-silica assemblage is stable over a very limited range of physical and chemical conditions, so it can be used to constrain the magmatic temperature and composition of the ALH84001 parent melt. In particular, liquidus relationships along the silica saturated surface of the pyroxene phase volume [1] indicate that the orthopyroxene-silica assemblage is stable when magmatic temperatures are  $\geq 1400^\circ\text{C}$ . Since cristobalite rather than tridymite is stable when temperatures exceed  $1470^\circ\text{C}$  [2], that may be a reasonable upper limit for the temperature of the melt, although it is necessarily tentative because silica polymorphs can crystallize metastably.

**Depth of crystallization.** At  $1400^\circ\text{C}$ , tridymite is stable when the pressure is less than  $\sim 0.5$  GPa [2]. On the other hand, high-quartz is stable when the pressure exceeds 0.5 GPa. Since both polymorphs occur in ALH84001, we tentatively conclude that the system crystallized at  $\sim 0.5$  GPa, near the phase boundary between tridymite and high quartz. On Mars, this pressure corresponds to a depth of  $\sim 40$  km.

**Thermal evolution of Mars.** The magmatic temperature implied by ALH84001 is higher than the eruption temperatures of modern terrestrial basalts. However, it is consistent with the high magmatic temperatures expected soon after the accretion of a planet. As the planet evolved, these tempera-

tures would have declined. Based on the liquidus temperatures of shergottite basalts [3], it appears that magmatic temperatures decreased by  $\sim 150$  to  $200^\circ\text{C}$  between 4.5 Ga and 180 Ma on Mars. Crustal temperatures are also likely to have been very warm early in Mars history and to have subsequently decreased with time. While it not clear how warm the crust of Mars is now, pyroxene compositions in ALH84001 [4] suggest crustal temperatures were  $>875^\circ\text{C}$  at the depth where ALH84001 crystallized 4.5 Ga.

**Chondritic Mg/Si ratio.** The silica in ALH4001 indicates the parent melt was silica oversaturated and the orthopyroxene-silica assemblage implies it had an atomic Mg/Si slightly less than unity, confirming previous assumptions of a bulk chondritic ratio in Mars [5]. In contrast, a large non-chondritic Mg/Si has been inferred for Earth based on the compositions of mantle xenoliths [6]. Strictly speaking, this large Mg/Si ratio represents compositions in the upper mantle and not necessarily the bulk Earth. It has been suggested that Si is sequestered in the lower mantle or core of the Earth, or that Si was preferentially lost due to volatility during accretion. If so, similar fractionation processes do not seem to have affected Mars. Alternatively, part of the difference in the Mg/Si ratios between the two planets may reflect intrinsic differences in the compositions of nebular materials in their respective accretion zones.

**References:** [1] Huebner J.S. (1980) *Pyroxenes: Reviews in Mineralogy*, 7, 213-288. [2] Hurlbut C.S. Jr. and Klein C. (1977) *Manual of Mineralogy (after James D. Dana)*. [3] Stolper E. and McSween H.Y. Jr. (1979) *GCA*, 43, 1475-1498. [4] Treiman A.H. (1995) *Meteoritics*, 30, 294-302. [5] Wanke H. and Dreibus G. (1988) *Phil. Trans. R. Soc. Lond.*, A325, 545-557. [6] Jagoutz E. *et al.* (1979) *Proc. Lunar Planet. Sci. Conf.*, 10th, 2031-3050.